Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Engineering 15 (2011) 4331 – 4336
Procedia Engineering
www.elsevier.com/locate/procedia

Advanced in Control Engineering and Information Science

Current Status and Prospect of Roller Bearing Surface Defect Detection

Huinan Wang[a], Jianxi Yang[a], Zhendian Hu[b], a*

[a]*School of Mechatronics Engineering,Henan University of Science and Technology,Luoyang 471003,China*
[b]*Hurun Wanjia Company, Shenzhen, 518020,,China*

Abstract

The current status of roller bearing surface defect detection are introduced, the advantage, disadvantage, practicability, developing trend and improvement problem in the future of every testing technology are discussed. It is pointed out that the machine vision method will play an important role in developing the auto-detecting system for roller bearing surface defect inspection.

Key words: Magnetic particle testing, Eddy current testing, Acoustic vibration, CCD, Machine vision;

1. Main text

Rolling bearing is the most widely useful basic part in machinery industry, which has large batch production and high precision. The accuracy of rolling bearing directly affects the motion accuracy of mechanical and electrical equipment. If there are defects that will cause some damages in the surface of bearing's parts, which will arouse vibration and noise, lead to reduce efficiency of the machine, shorten the lifetime and increase the dangerous coefficient, terrible risks will exist in the accident. Therefore, surface defect detection technology of rolling bearing parts is attached more importance to rolling bearing industry. And, it is the important puzzle in the rolling bearing industry to increase the surface quality of rolling bearing parts and then to increase the motion accuracy of rolling bearing. As the important part, as

* Huinan Wang. Tel.: +086-379-64277971; fax: +086-379-64277971.
E-mail address: huinan1117@163.com.

doi:10.1016/j.proeng.2011.08.813

to the roller bearing, it deeply affects the rotation accuracy, motion property, use lifetime of rolling bearing [1]. Thence, it is necessary to test the roller surface defect strictly.

2. Artificial visual detection

At present, domestic bearing manufacturer mostly adopt artificial visual detection to test the surface detection of the roller, mainly by observing defections with eyes and feelings, and to judging if there are spots or cracks in roller bearing by the appearances, with tester's technical experiences. The ways as follows: people pull the rollers that are irradiated by a beam of strong light on the working table, back-and-forth rotating them and observe if there are defections [2]. However, because the capacity of the visual inspection is terminate after all, there will be amount of wrong and lost detections of roller bearing surface defect. There are many disadvantages about artificial visual detection: fist, the detecting results are influenced by testers' subjective factors, such as qualities, experiences, so they are not accurate and specificity, affecting to monitor effectively the production qualities; second, quantitative assessment requirements provided in the process standard are often difficultly executed accurately [3]; third, because the speed of visual detection is slow, and work efficiency is low, this way not adapt to the demands of modern industry large-scale, and can't realize auto assembly line product process of large quantity and high quality and the demands of rate of zero waste testing. Therefore, artificial visual detection always don't adjust to the demands of modern industry development.

3. Magnetic particle testing and Eddy current testing

3.1. Magnetic particle testing

Magnetic particle flaw detection is a common way for nondestructive testing, which is used in detecting the defections in surface of the parts and near-surface of ferromagnetic material. Its testing basic principle is: firstly a magnetic field is built in the tested piece, when this piece is being magnetic, if there are cracks or stomas in the surface of this piece or near-surface, magnetic lines of force will be changed in the area of defection. Some of them is out to be partly magnetic pole, and then leakage magnetic field is formed in the defection position, which will adsorbed and gather exerted magnetic particle that are very minor in the testing process, forming apparent magnetic marks that can be observed with eyes and providing defections. The piece defections are defined by observing existence and distribution of magnetic trace, and whether there are defections in the observed piece is judged by the related standard boundary for flaw detection [4,5].

In the near-surface and area where the extension direction and the direction of magnetic lines of force are vertical, the defections are easily found by magnetic particle flaw detection. Roller's surface need to be cleaned before flaw detection, and roller need to be demagnetized after flaw detection. Large-scale rollers can't be detected flaw simultaneously because of the operating environment limit. So, it is difficult to detect surface defections such as uneven material, magnetic injury and pitting. In view of some advantages of easy operation, simple equipments, intuitive and quick observation defections, reliable and quick results and low price, this way is always widely applied to aviation, aerospace, Metallurgy, petroleum and so on [6].

Zhang Ying in the Changchun University proposed magnet powder flaw detection system for a train's axletree roller surface based on CCD imagining [7]. Automatic magnetic powder flaw detection system is controlled by computer to complete auto-detection with the high precision CCD camera acquisition image on the base of mature magnetic powder testing technology. The way is as follow: after the roller is magnetized, fluorescence magnetic particle suspensions are sprayed on its surface. Those fluorescence

magnetic particles in the defection area will shine under the stimulation of UV, then they will be taken the photos by high precision CCD. After that the related pictures will be handled appropriate by computer to enhance demonstration and to warn, print suspect defection pictures in time. This auto testing system consists of computer, magnetic particle flaw detection machine, control section, optical section, image processing section, stepper motor and so on. Fig 1 is as follows. At present, auto magnetic powder flaw detection technology focuses on extracting and distinguishing defections and running all the system reliably.

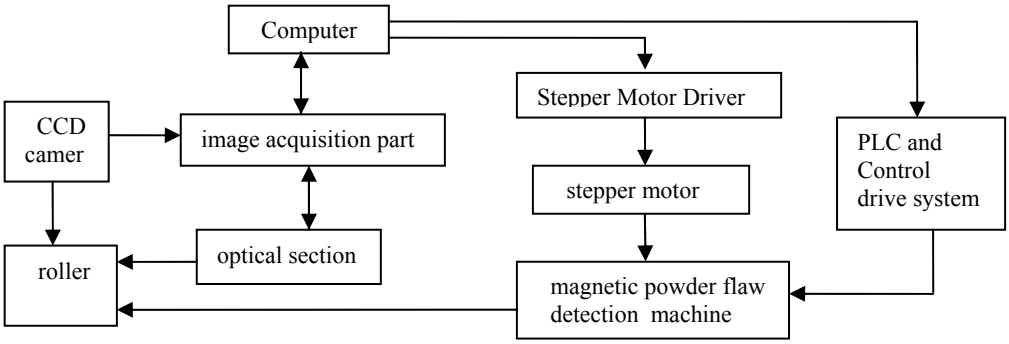

Fig.1 magnetic powder detection system

3.2. Eddy current testing

Eddy current testing technology, which is based on the electromagnetic induction theory, set up the rolling bearing roller in the alternating magnetic field, and then there will be induced current in the roller, that is eddy current. The function of this eddy current magnetic field produced by itself in the roller is to change strength of original magnetic field, then inducing the diversification of coil voltage and impedance. When there are defections in the surface or near-surface of roller, the strength and distribution of eddy current will be influenced, which will lead to the change of coil voltage and impedance. According to this diversification, whether there are defections in the roller will be detected [8].

Eddy current testing expresses good testing effects, but it is too insensitive to other apparent defections to realize comprehensive test about all the surfaces of pieces. Therefore, it is inevitable to emerge some wrong and lost detection; the accuracy demand of the applied testing equipment is high and the testing signal is weak and it is difficult to identify. Besides, there are so many interference factors.

Pang Chuanpin proposed a new method that combines eddy-nondestructive testing technology with error separation theory to detect the roller bearing surface defection of the rail vehicles [9]. The roller bearing surface is detected with eddy current testing technology, and when the gap variation that exists between probe and roller surface is changed, coil impedance will be changed, according to the eddy current effect produced by metallic conductor in AC magnetic field. Because the changing degree is related with resistivity and permeability of metal plate and gap size, these factors will be changed when there are cracks, nicks and damages in the roller surface, and will be showed by some signal collected from eddy current sensor. Rotation error signal, size error signal and shape error signal of the piece are separated by related mathematical model establish by error separation theory, and then surface defection information of the tested roller will be detected. In the following research, it is to be resolved mainly that the quantitative judgments of defection detection, defection detection of continuous many sections, storage and management of testing data, auto control of testing process and design and manufacture of

mechanical transmission and so on are, which cause that this system will be more suit to actual production.

4. Acoustic vibration

Zhou Jingliang from Fujian engineering institute proposed that surface cracks of roller bearing are detected nondestructive with acoustic vibration [2,10]. These cracks change the original vibration modal parameters of roller structure, so whether there are cracks defections in the roller can be distinguished by impulse response features. The audio-spectrum characteristics of roller bearing is analyzed with the way of tapping acoustic vibration, and then according to excitation roller bearing, some related parameters and the spectral characteristics of roller itself structures will be got to achieve detection of crack defections in the roller surface nondestructive. The forms of the roller cracks mainly contain material cracks, forging cracks, hardening cracks and grinding cracks. From the vibration analysis, if there are cracks about the structure, theirs damping coefficient and stiffness will be changed, which will reflect on damping ratio and natural frequency. Damping ratio of the structure is increasing with the extension of the cracks, while natural frequency is reducing. Because the vibration transmission is obstructed by the increase of damping ratio, the structure with cracks has more quick attenuation and theirs frequency components become lower than that without cracks after suffering the same impact; The sound from structure with cracks is low-spirited and husky after suffering impact; while the sound from that without cracks is crisp.

According to appropriate excitation roller bearing with acoustic vibration to analyze audio-spectrum characteristics, whether there are crack defections is judged by distinguishing the mode of audio-spectrum characteristics with artificial neural networks. Acoustic vibration depending on testers' experience in traditional is avoided with this way, and it can resolve some difficulties in testing caused by location of cracks of roller bearing and arbitrary of the size of cracks, and the influence in research results from environmental noise can be eliminated.

5. Optical detection

Machine vision regards the image processing theory as the core, which is an area of artificial intelligence and is applied to all kinds of nondestructive detection technologies [11]. Machine vision take camera and computer replace of eyes to identify, track and measure the productions. The appearance of machine vision based on computer vision provides a new way of testing for us. Firstly testing target is transformed to image signals by CCD camera, and then these signals are transformed to digital signals by image acquisition card that are sent to dedicated image processing system. According to same information such as pixel distribution, brightness and color, the target features are extracted by various mathematical operations. And the results are exported according to pre-setting tolerance and other conditions [12].

Machine vision is a comprehensive technology, which contains digital mechanical engineering technology, image processing technology, illumination technology, control technology, simulation and video technology, optical imaging technology, sensor technology, computer hardware technology and human interface technology [13]. Typical industry machine vision is shown as figure 2. Machine vision stresses on adapting to hostile environment in the industry site, having reasonable cost-effective, stronger versatility and portability, that is usefulness; and also stresses on high speed and accuracy, that is real-time. Its key technologies in the applying system mainly reflect in illumination, optical lens, CCD, image acquisition card, image signal processing and executive institution [14]. Auto identifying detection with machine vision has already been applied in the production appearance and surface defection detection, such as vision detection about metal surface, substrate detection about diode, defection detection about printed circuit board, auto-identifying weld defection. And these testing identify systems belong to 2D

machine vision, whose technologies are mature [13]. At present, machine vision is successfully applied to the industry detection area, which substantially increases the production quality and reliability, guaranteeing the manufacture speed [12].

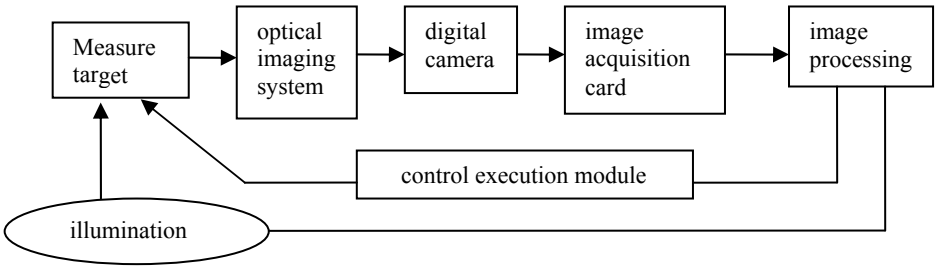

Fig.2 typical industry machine vision application system

Cai Shanle from Lanzhou University of technology provided the researching system about detection on surface defection of roller bearing based on CCD imaging [15,16]. The target is transformed to video signals by CCD that are sent to image acquisition card, and then these signals are sent to image processing system to be processed after being analyzed and digital. The last, these signals will be programmed with LabVIEW software. CCD imaging testing system mainly contains three parts: getting image, processing and analyzing image, outputting and showing image. If surface defection of roller is detected, firstly the images need to be pre-processed and image segmentation; secondly the defection image will be received by comparing with standard roller image. Defection identifying Flow chart is shown as figure 3. This testing system can greatly reduce the detecting cost, and possesses the advantages of reliability and high speed, creating a comfortable working environment. Image processing program, which is edited in LabVIEW, has intuitive interface, simple operation, strong analyzing function, and will be a developing trend of nondestructive detection .

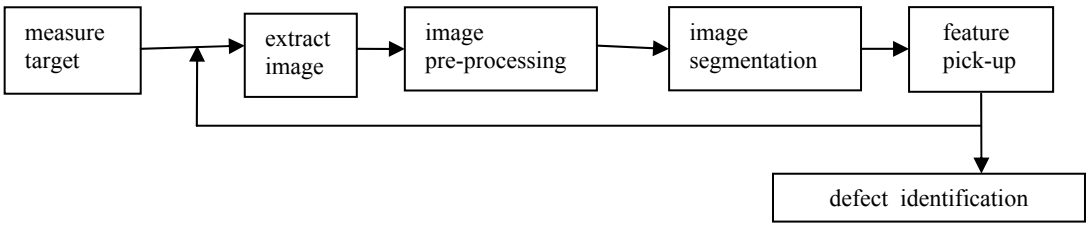

Fig.3 flowchart of defect identification

6. Conclusion

The roller bearing defection detection mainly is applied to inner cracks testing researches, while surface defection detection of roller bearing mainly adopts artificial visual detection in practical application. In fact, there are their characteristics and applying ranges and their disadvantages in these testing technologies above mentioned. Compared with other technologies, CCD testing system possesses some features such as high testing accuracy, quick processing speed, non-contact measure, high resolution, strong anti-jamming capability, better resistance to vibration impact, and stable running, which make the testing way based on CCD image as the mainstream in research working at present. However, it has not general digital signal processing platform and special algorithm of image processing and pattern

recognition on this method [17]. With the development of computer technology and the aging of neuron theory and pattern recognition technology, machine vision testing technology will contribute to roller bearing surface defection detection.

At present, machine vision is greatly applied to testing production surface quality. The auto-testing way possesses some features of high accuracy, high speed, objective testing results, lower cost, meeting the demands of modern manufacturing to detection. With the improving of production automation and scale, appearance testing way based on machine vision will be applied and developed in testing area nondestructive detection. Therefore, it is more important to adopt auto-testing system on line based on machine vision technology to detect surface defection of cylindrical roller bearing in the production area.

References

[1] Guilan LIU. The research of the automatic detection system of roller bearing surface defect. *Lanzhou Univerdity of Technology*. Master thesis.2009;04,20.

[2] Jinglian ZHOU, Zhixi Lin, Yaozhi Huang. Nondestructive detected of roller bearing with acoustic vibration. *MECHANICAL & ELECTRICAL TECHNOLOGY* .2006,29(4)36-37.

[3] Ping ZHANG,Zhenghong Zhu. Machine vision technique and its application to automation of mechanical manufacture. *Journal of hefei university of technology*.2007,30(10)1292-1295..

[4] Haibin WU,Jie Zhang,Jun Chen. Phosphor magnet powder flaw detection methods for a tyre surface based on CCD imageing and image research. *JOURNAL OF ATMOSPHERIC AND ENVIRONMENTAL OPTICS*. 2006,9(2)155-160.

[5] Cuili CHEN. Fluorescent magnetic flaw detection discussion and its applications. *Bearing* 2008(1)30-32.

[6] Le ZHOU,Zhiwen Zhang. Nondestructive testing and its new technology. *Journal of chongqing institute of technology*. 2006,20(8)46-48.

[7] Ying ZHANG. Magnet powder flaw detection system for a train's axletree roller surface based on CCD imaging. *J.Changchun Inst Tech*(Nat Sci Edi),2009, 10(1)59-60.

[8] Changying Xu,Chunfa Gao,Kangjing Weng. The development and application of steel ball's automatic testing technology .

[9] Chunbin PANG, Huifen JI. Probe into computer testing system for the surface defects of the bearing rollers of the stocks. *SCI/TECH INFORMATION DEVELOPMENT & ECONOMY*.2002,12(5)69-71.

[10] Jingliang ZHOU,Zhixi Lin,Yaozhi Huang. Data acquisition and processing of nondestructive testing for bearing roller. *Journal of fujian university of technology*. 2007,5(1)79-82.

[11] Shuibi LIAO,Mingfu Xiao. Current status and prospect of metal surface defect nondestructive inspection. *China Metallurgy*. 2007,17(3)48-51.

[12] Feng DUAN,Yaonan Wang, Xiaofeng Lei. Machine vision technique and its applications. *Auto-expo*. 200(3)59-62.

[13] Wei ZHANG.Development of machine vision and its industrial applications.*INFRARED.*2005,27（2）11-17.

[14] Wuyi ZHANG,Qiangsong Zhao,Dongyun Wang. Actualities and developing trend of machine vision. *JOURNAL OF ZHONGYUAN UNIVERSITY OF TECHNOLOGY*. 2008,19（1）9-15.

[15] Shanle CAI,Guilan Liu,Bo Zhang. The research of the appearance detection system of roller bearings based on image technology. *New technology*.2009（4）42-43.

[16] Shanle CAI,Guilan Liu,Songbing Yang. The research of the defective detection system of surface of roller bearings on the basis of CCD imaging. *MECHATRONICS* .2008（2）68-69.

[17] Fangqing JIA. The research of the surface defect inspection system of steel strips based on machine vision. *Chongqing University*. Master thesis.2007;4,20.